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Publication No. 1496

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An Efficacy Review of Control Measures for Potential Pests of Imported Soviet Timber

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An Efficacy Review of Control Measures for Potential Pests of Imported Soviet Timber

Executive Summary

Based upon an extensive pest risk assessment on importing Siberian logs (primarily larch) prepared by the U.S. Department of Agriculture's (USDA) Forest Service (FS), the Animal and Plant Health Inspection Service (APHIS) compiled a detailed inventory of the various pest mitigation measures available. This inventory follows the FS grouping of specific pests and pathogens into three broad categories, according to the niche they occupy: (1) on the outer surface of the bark (as hitchhikers), (2) in or under the bark, or (3) in the wood. The present report discusses potential mitigation measures in terms of their expected efficacy against the pest in each category and cites appropriate scientific literature.

At this time, there are many gaps in the scientific data on this subject. However, in general, debarking and/or chemical treatment (done in the Soviet Union), followed upon the logs' arrival in the United States by heat treatment, appears to be the best option. Suitable safeguards and APHIS supervision are essential if Siberian timber is to be allowed entry into this country.

Mention of companies or commercial products does not imply recommendation or endorsement by the U.S. Department of Agriculture over others not mentioned. USDA neither guarantees nor warrants the standard of any product mentioned. Product names are mentioned solely to report factually on available data and to provide specific information.

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Chapter 1—Introduction

Approach

This report provides the technical basis and operational framework for developing systems to mitigate the risks inherent in the importation of Soviet timber. To obtain the necessary information about potential risks in this importation scenario, APHIS asked the FS to:

- Identify exotic organisms with the potential to be pests that may infect or infest unprocessed logs from Siberia and the Soviet Far East.

- Assess the potential for colonization of groups or individual pests during the process of importing, transporting, processing, and utilizing such logs.

- Assess the potential impacts of organisms so identified, should they become established in the United States.

A process for conducting this pest risk assessment was designed by APHIS and provided to the FS. This process focused the pest risk assessment so that its outcomes could be used by APHIS in assessing mitigation measures.

These assessments will support subsequent decisions by APHIS on overall conditions for managing proposed importations of Siberian logs.

First, the FS team identified the timber types likely to be requested for importation: larch, pine, spruce, and fir. Next, the FS compiled inventories of potential pests that could be introduced if Siberian timber of these tree species were imported. The detailed pest assessment focused on larch because of the immediacy of potential importation and because most of the initial imports are expected to be of this species. The FS team selected key pests of larch for detailed assessment as representatives of the broader categories—insects, plant diseases, and nematodes. In the report, pests were further grouped according to their particular niche in imported timber to facilitate subsequent assessment of the pest mitigation measures.

In the FS' comprehensive report to APHIS, specific assessments were provided on 36 representative insect pests, wood nematodes, and diseases. Subsequently, APHIS inventoried potential mitigation measures and evaluated them for technical efficacy against each of these organisms.

APHIS' Science and Technology unit provides agency programs with technology and technical support services. This group developed an inventory of state-of-the-art mitigation measures for timber pests and defined the efficacy of these measures for the organisms identified in the FS pest assessment.

This two-part assessment will provide a basis for subsequent development of methods for safe importation of Soviet timber.

Background

In mid-1990, two small-scale shipments of Siberian logs entered the United States for processing at Eureka, CA, under a protocol jointly developed by the California Department of Food and Agriculture and APHIS. No further importations have occurred since that time because USDA imposed a temporary ban on importation of Soviet logs until appropriate scientific data on Soviet forest pests could be compiled and assessed.

Trees produced in temperate areas outside North America are affected by a wide variety of pests and diseases that do not occur on this continent. Logs imported from the U.S.S.R. could pose a significant hazard of introducing pests and diseases detrimental to U.S. forest production, recreation, and urban forest resources. Currently, except for the interim ban on Soviet logs, there are no specific Federal regulations restricting the entry of imported logs.

During the last 3 months of 1990, APHIS worked with regulatory and forestry professionals from the FS, Agriculture Canada, the States of California, Oregon, and Washington, and key industries with an immediate interest or involvement in potential importations of forest products from the U.S.S.R. The objective of this effort was to define the conditions under which logs could be imported, both on a test basis and long term. While significant progress was made in understanding both the risks and potential mitigative measures, data in both areas were insufficient. This cooperative venture has, however, been successful in defining the issues.

The FS put in place a pest risk assessment team that included an APHIS representative to lead a scientific assessment of relevant pests and their significance. This effort involved the best scientific resources from the public and private sectors. Concurrently, an APHIS management practices team assessed mitigation measures and developed and evaluated alternatives for managing risks. This effort was aimed at determining if feasible alternatives were or would be available or if the ban on imports should continue. The two teams operated concurrently so that decisions on further action could be made as soon as possible after the delivery of this two-part assessment report.

A complete, full-scale assessment of pests of larch was provided to APHIS by the FS on June 30, 1991. This analysis identified potential quarantine pests and defined the risks from importation of logs from the Soviet Far East and Siberia.

General Importation Requirements

Through regulations and procedures stipulating conditions of entry, APHIS facilitates the safe importation of commodities that pose potential plant-pest risks. APHIS approves specific systems for importation of products to keep the pests and diseases that may be associated with such commodities from entering and becoming established in the United States. Three types of activities comprise this agency effort:

1. Inspection and detection activities.

2. Prevention: The imposition of safeguards to reduce or eliminate pests of quarantine significance on the commodity prior to its presentation for entry into the United States.

3. Pest mitigation at the port of entry: The use of physical or chemical treatments to eliminate pests or diseases of quarantine significance.

In cases where APHIS determines that the risks of pest escape are acceptably low, such treatments may be performed at the U.S. port of entry. In other cases, such treatments must be completed prior to the commodities' entry at U.S. ports. All quarantine treatments and safeguards must be conducted directly under the supervision of an APHIS official or be independently verifiable through the use of automated recording equipment or other automated means throughout the treatment process.

For treatments to be approved for regulatory purposes, data are required which demonstrate elimination of the pest hazard in the commodity. Such data are generally developed by independent researchers according to agreed-upon research plans or protocols.

Another general requirement for all imported products is that they be free of soil. Soil as a contaminant from all foreign sources is prohibited. To be enterable, any product or article determined to be contaminated with soil must be cleaned or treated if it is operationally feasible to do so. If a soil-contaminated product cannot be cleaned, it is refused entry into the United States.

APHIS has concluded that the following conditions must be met before importations of Soviet logs may be authorized:

- Logs of Soviet origin with or without bark cannot be allowed to be carried abovedeck on a vessel unless appropriate mitigative measures have been applied to preclude the escape of pests. (Insects and spores can become airborne and pose a risk to native forests while the ship is in port.)

- Any quarantine treatment would have to be:
(1) approved as efficacious,
(2) conducted in a manner prescribed by APHIS,
(3) supervised or verifiable by an APHIS employee, and
(4) environmentally acceptable and in compliance with Federal and State regulations.

- Timber products must be free of soil at the time of entry. APHIS does not consider the management and treatment of such contamination at ports of entry to be feasible for large shipments. Thus, this requirement alone would generally lead to refusal of the shipment, and reexport of the entire shipment would be mandatory. For the purpose of eliminating soil contamination, inspection and preclearance of logs in the Soviet Union by APHIS personnel sent on temporary duty is possible. However, the costs for this service would have to be borne by the American forest-products industry.

Chapter 2—Inventory of Mitigation Measures

Approach

APHIS' Science and Technology unit is responsible for the efficacy and design of quarantine treatments.

The staff of the Methods Development Center at Hoboken, NJ, was assigned to review data on forest insects and their applicability to this situation. That center, established in 1941, has accumulated an extensive collection of publications dealing with regulatory treatments for quarantine-significant pests and pathogens of agricultural commodities worldwide. This collection and computerized literature searches of the material at the National Agricultural Library in Beltsville, MD, were utilized in this review.

The following report presents a review of the applicability of existing data to the pests and pathogens identified by the FS' pest risk assessment team. To help provide direction for the research still remaining to be done, this report also identifies gaps in efficacy data for treatments.

Methyl Bromide Fumigation

Methyl bromide (CH_3Br) is a nonflammable, colorless, odorless fumigant with a specific gravity of 1.732 at 0 °C. It boils at 38.48 °F (3.6 °C), has a very low solubility in water, and as a gas is three times as heavy as air (Munro 1969a). The fumigant operator must avoid personal exposure to all concentrations. The threshold limit value to humans (the concentration of gas below which it is considered safe to breathe) is 5 parts per million (p/m).

Methyl bromide is very effective against plant pests, including all stages of insects, mites, snails, slugs, and nematodes, as well as most fungi. Its effectiveness as a fumigant was discovered in 1932. Since then, it has become the fumigant of choice in quarantine treatments.

Methyl bromide diffuses laterally and downward readily, and upward slowly. These characteristics make blower or fan circulation essential, at least during the first 15–60 minutes, to ensure thorough gas distribution. In addition, circulation enhances penetration. A volatilizer is required when introducing methyl bromide. Products to be fumigated must be enclosed by a chamber or tarpaulin.

During fumigation, the gas concentration is monitored at various times by the use of a portable halide gas thermal conductivity analyzer. These instruments are specifically designed for determining the concentration of gases within a chamber or other enclosure while the actual fumigation is being conducted. Polyethylene sampling tubes are used to obtain fumigant concentrations from selected areas within the tarpaulin enclosure. Gas leakage may be detected by use of a halide leak detector whose flame turns from yellow to green to blue in the presence of increasing amounts of methyl bromide. When this gas is used for fumigation of enclosed spaces (e.g., chambers, ships, trucks, and tarpaulin-covered commodities), the label states that two persons trained in the use of methyl bromide must be present during its introduction, at initiation of aeration, and after aeration when testing for reentry. APHIS requires that one of its officers be present when gas concentrations are measured, to ensure the efficacy of the fumigation. If readings indicate there is insufficient gas present, corrective action must be taken.

Methyl bromide is effective at commodity temperatures of 40 °F (4.5 °C) and above. In general, an increase in commodity temperature gives a corresponding increase in effectiveness. The temperature used in calculating dosage is that of the commodity itself, rather than air temperature. After completion of fumigation, the commodity is aerated with blowers or fans until the exhaust gas contains no more that 5 p/m of methyl bromide. Aeration is monitored by using colorimetric detector tubes.

Methyl bromide has been used successfully to fumigate wood and wood products containing bark beetles and borers, termites, and the fungus that causes oak wilt disease. In addition, its efficacy against nematodes in wood looks promising, based upon ongoing FS research (L.D. Dwinell, pers. comm.). Methyl bromide has also been used routinely to fumigate soil for soil-borne fungi, nematodes, and other insects.

Methyl bromide is considered to be the most penetrative of all fumigants. It penetrates oak by several inches, sufficiently to kill oak wilt fungus (Liese and Ruetze 1985). Siberian timber species being proposed for import are all conifers (softwoods) and should pose even less of an obstacle to penetration by the gas than does oak (a hardwood). More-rapid penetration could be expected if fumigation is done in a vacuum chamber, though fumigation under tarpaulin, under normal atmospheric pressure, is the standard and has been shown to be an effective treatment. Extensive research by Michelsen (1964) showed that penetration of methyl bromide into wood is inversely proportional to the wood's moisture content; also, radial diffusion (against the grain) is many times slower than longitudinal diffusion (along the grain). For pine timber, radial diffusion was at 0.4 to 0.9 cm/h, compared to longitudinal diffusion of 3 to 24 cm/h. In another study, Ricard et al. (1968) reported that in debarked Douglas-fir logs, methyl bromide was detected within 30 minutes in logs up to 19 inches in diameter. The presence of bark on logs presumably slows or reduces the penetration of methyl bromide; however, oak logs in the United States are routinely fumigated to kill oak wilt fungus quite successfully. The exposure periods must be very long, though—72 hours for logs and 48 hours for lumber. Bark removal eliminates many pests and aids in the penetration of the methyl bromide deep into the interior of the timber.

The following fumigation schedules, taken from Section VI of APHIS' Plant Protection and Quarantine (PPQ) Treatment Manual (1985), are typical. Schedule T312 (a) and (b) were based upon research by Liese and Ruetze (1985). Schedule T404 was based upon the work of Harris (1963 a, b).

T312 Oak Logs and Lumber for Oak Wilt Disease
(a) Logs

Methyl bromide at normal atmospheric pressure

240 g/m^3 (240 oz/1,000 ft^3) for 72 h
at 5 °C (41 °F) or above
(240 g minimum concentration at 1/2–2 h)
(200 g minimum concentration at 12 h)
(120 g minimum concentration at 24 h)

After the 24-h period, add additional fumigant to bring concentration up to 240 g (oz).
(160 g minimum concentration at 36 h)
(120 g minimum concentration at 48 h)
(80 g minimum concentration at 72 h)

Followed by: Aeration for 48 h.

(b) Lumber

Methyl bromide at normal atmospheric pressure

240 g/m^3 (240 oz/1,000 ft^3) for 48 h
at 5 °C (41 °F) or above
(200 g minimum concentration at 1/2 h)
(160 g minimum concentration at 2 h)
(100 g minimum concentration at 12 h)
(40 g minimum concentration at 24 h)

After the 24-h period, add additional fumigant to bring concentration up to 240 g (oz).
(120 g minimum concentration at 36 h)
(80 g minimum concentration at 48 h)

Followed by: Aeration for 48 h.

T404—Wood Products, including containers
(a) Borers (wood wasps, Cerambycids, *Dinoderus*)

(1) Methyl bromide at normal atmospheric pressure

a. Chamber or tarpaulin

48 g/m^3 (48 oz/1,000 ft^3) for 16 h
at 21 °C (70 °F) or above
(36 g minimum concentration at 1/2 h)
(30 g minimum concentration at 2 h)
(27 g minimum concentration at 4 h)
(25 g minimum concentration at 16 h)

80 g/m^3 (oz/1,000 ft^3) for 16 h
at 4.5–20.5 °C (40–69 °F)
(60 g minimum concentration at 1/2 h)
(51 g minimum concentration at 2 h)
(46 g minimum concentration at 4 h)
(42 g minimum concentration at 16 h)

It should be emphasized that APHIS does not have methyl bromide efficacy data on many specific pests and pathogens of concern on Soviet timber. However, the prospects for success in using methyl bromide for this fumigation application appear to be good.

For both safety and efficacy reasons, APHIS does not recommend intransit fumigation on seagoing vessels.

It may be feasible to fumigate logs aboard ship while in port. Section III, part 6 of the PPQ Treatment Manual covers this procedure in detail. We recommend, however, that all ships be preinspected by a PPQ officer before loading, for approval of each ship on a case-by-case basis. Some ships cannot be approved because of extensive ductwork inside the holds, making tight seals impossible. Ships dedicated solely to hauling logs could be required to have permanently installed fans and gas-sampling leads.

All permits to fumigate aboard ship must be obtained in advance. These include local, State, Coast Guard, U.S. Environmental Protection Agency (EPA), and APHIS requirements. Environmental concerns include the health of both human populations and wildlife.

Frozen logs present a dilemma. Fumigation is ineffective if the commodity temperature is below 40 °F. For this reason, shipboard fumigation during cold weather could be done only belowdeck, with provision for adding heat to warm the logs before and, if necessary, during fumigation. If warming the logs is not feasible, shipboard fumigation will have to be restricted to the warm season.

Shipboard fumigation is always a cumbersome process, requiring considerable expertise on the part of the fumigator. The ship must be docked in a secure area (free of unauthorized personnel, including crew) during treatment and aeration. Total treatment time can easily require 1 week. The fumigant can drift for some distance during aeration. A self-contained breathing apparatus (SCBA) must be used whenever methyl bromide concentrations exceed 5 p/m.

The PPQ Treatment Manual (section III, part 6) contains detailed regulations concerning shipboard fumigation. Appended to this are the applicable U.S. Coast Guard regulations, originally published as 46 CFR, Chapter 1, Part 147A, October 1, 1976.

There have been few studies published on shipboard fumigation of logs. However, Yu et al. (1984) reported that 100 percent of insect pests on logs were killed when fumigated onboard ship with methyl bromide at 25 g/m^3 for 24 h at 10 to 20 °C or at 37.5 g/m^3 for 16 h at the same temperature range. Insects in the Yu study included Lyctid borers (*Lyctus lineraris*), shot-hole borers (Platypodidae), five species of bark beetles (Scolytidae), and several hitchhiking surface pests. These species are related to but not the same as those found on Siberian logs.

Additional references on ship fumigation (not specifically on logs) include the following: Anonymous (1947), Slobodnik (1962), Munro (1969b), and National Pest Control Association (1972).

References Cited on Methyl Bromide

Anonymous. 1947. Methyl bromide speeds ship fumigation. Down to Earth 3(3):10-11.

Animal and Plant Health Inspection Service. 1985. Plant Protection and Quarantine treatment manual. Washington, DC: U.S. Department of Agriculture, Animal and Plant Health Inspection Service: Sec. 3, pt. 6.

Harris, E. C. 1963a. Methyl bromide fumigation for wood-boring insects. International Pest Control 5(4): 15-18.

Harris, E. C. 1963b. Methyl bromide fumigation and wood-boring insects. In: Proceedings of the annual convention of the British Wood Preservation Association; London, UK. [Place of publication and publisher unknown.] 17 p.

Liese, W.; Ruetze, M. 1985. Development of a fumigation treatment of oak logs against *Ceratocystis fagacearum*. European Plant Protection Organization Bulletin 15(1): 29-36.

Michelsen, A. 1964. Diffusion of methyl bromide into pine wood during fumigation against *Hylotrupes bajulus*. Holzforschung und Holzverwertung 16: 66-71.

Munro, H.A.U. 1969a. Manual of fumigation for insect control. Rome: Food and Agriculture Organization of the United Nations: 121.

Munro, H.A.U. 1969b. Insect pests in cargo ships. Publ. 855. Ottawa, ON: Agriculture Canada. 39 p.

National Pest Control Association. 1972. Good practices in ship fumigation. Tech. Rel. 18-72. Vienna, VA: National Pest Control Association. 10 p.

Ricard, J. L.; See, T. E.; Bollen, W. B. 1968. Control of incipient decay with gases in Douglas-fir poles. Forest Products Journal 18(4): 45-51.

Slobodnik, M. 1962. Fumigating ships in harbor. Pest Control (July): 30-32 ff.

Yu, K. Y.; Chung, Y. W.; Lee, H. H.; Jae, J. W. 1984. Study on shipboard fumigation of the imported logs. Korea Journal of Plant Protection 23(1):37-41. [In Korean; English summary.]

Phosphine Fumigation

Phosphine (PH_3), also known as hydrogen phosphide, is generated either from aluminum phosphide or magnesium phosphide. Phospine is available under various trade names in the form of pellets, tablets, bags, and plates.

In the presence of moisture, aluminum phosphide or magnesium phosphide undergoes a chemical reaction that liberates phosphine gas, which is colorless. Phosphine boils at -126 °F, is slightly soluble in water, has excellent penetrative power, and has approximately the same density as air. The lower limit of flammability is 1.79 percent in air. Phosphine has a carbide odor resembling garlic; therefore, the gas serves as its own warning agent. However, in some conditions this odor is lost. Under high humidity, certain metals (e.g., copper alloys, gold, and silver) are severely damaged by exposure to phosphine. Any electrical equipment containing these metals may be ruined by phosphine fumigation.

Phosphine fumigation is normally done under tarpaulin or in a van or container. Fans or blowers are unnecessary during fumigation because this fumigant has approximately the same density as air. Phosphine fumigations are relatively long in duration (3–5 days) because of the time required for the aluminum phosphide or magnesium phosphide to react with atmospheric moisture. A pest-control operator must be available to take gas concentration readings at intervals during the fumigation. Halide or any flame detectors are not to be used with phosphine. Colorimetric detector tubes are used for determining both fumigation concentrations and personnel-safety levels of phosphine. After completion of fumigation, the gas is expelled by means of fans or blowers until the threshold limit value of 0.3 p/m is reached.

Phosphine is used throughout the world to kill insects found in both plant and animal commodities, especially stored products. It is effective against all insect life stages. For most insects, long exposure to low concentrations is more effective than short exposure to high concentrations. Growing plants, fresh fruits, and vegetables are generally not tolerant to phosphine. Little or no information is available on the efficacy of this agent against snails or plant pathogens.

Research on pinewood nematode (*Bursaphelenchus xylophilus*) has shown that phosphine can be used to treat wood chips in transit on ships (Davis et al. 1987, Leesch et al. 1989), though the dosage level needed for 100-percent kill has not been determined. Further research is needed before APHIS could grant approval for phosphine treatment of logs. Efficacy data derived from the wood-chip studies may also apply to logs and lumber if gas penetration to the center of large logs can be demonstrated.

Guidelines and references on shipboard fumigation given in the methyl bromide section of this report would be applicable to phosphine fumigations.

It should be noted here that the North American Plant Protection Organization (NAPPO) took an official stand in 1989 on wood nematodes. NAPPO is of the opinion that the mere presence of nematodes in wood offers no potential for their establishment. NAPPO has concluded that it is more important for quarantine authorities to take action against cerambycid beetles, which serve as nematode vectors, rather than against the nematodes themselves.

The Plant Protection and Quarantine Treatment Manual (APHIS 1985) contains several phosphine fumigation schedules effective against various insects. The schedule applicable to wood borers is shown below based upon work by Richardson (1974):

T 404 (b) (3) (Wood Products, for borers, except termites)
Phosphine at normal atmospheric pressure

33 g/1,000 ft^3 (= 28.3 m^3) for 72 h
at 40 °F (4.4 °C) or above

Minimum concentration at 72 h: average of 225 p/m with no reading below 50 p/m.

The Phostoxin label prescribes "30 to 90 tablets" (which releases 30 to 90 grams of phosphine) per 1,000 ft^3 for use against "miscellaneous pests."

APHIS recommends that these fumigation schedules be tested on the specific pests and pathogens of Soviet timber before adoption as a formal quarantine requirement. The efficacy of phosphine against the pathogens specified in the FS risk assessment remains undetermined.

References Cited on Phosphine

Animal and Plant Health Inspection Service. 1985. Plant Protection and Quarantine treatment manual. Washington, DC: U.S. Department of Agriculture, Animal and Plant Health Inspection Service: Sec. 1, pt. 2.

Davis, R.; Leesch, J. G.; Simonitis, R. A.; Dwinell, L. D. 1987. The "Floriani" experiment: in-transit fumigation of wood chips to control the pine wood nematode. International Forest Products Transport Association Journal 4: 8-9.

Leesch, J. G., et al. 1989. In transit shipboard fumigation of pine wood chips to control *Bursaphelenchus xylophilus*. European Plant Protection Organization Bulletin 19: 173-181.

Richardson, H. H. 1974. Freight container fumigation and wood penetration with phosphine against termites and other insects. Pest Control 42(8): 20-22.

Sulfuryl Fluoride Fumigation

Sulfuryl fluoride (SO_2F_2) is a colorless, odorless, stable, nonflammable fumigant with a boiling point of -69 °F. It is practically insoluble in water, and as a gas is approximately 2.5 times as heavy as air. It is known in the trade as Vikane, a registered trade name of the Dow Chemical Company. Quarantine treatments often refer to it as "SF."

The gas must be monitored at intervals during fumigation by APHIS personnel using a thermal conductivity gas detector that has been calibrated for sulfuryl fluoride. Fans should be run during the fumigation for the first 15–60 min. At the conclusion of fumigation, the gas is exhausted until the remaining concentration reaches 25 p/m, at which time the tarpaulin may be removed. Protective gear must be worn. Aeration continues until the sulfuryl fluoride concentration in the vicinity of the commodity is at or below 10 p/m, the short-time exposure limit for humans. Because colorimetric "detector" tubes are not available to detect sulfuryl fluoride, the use of more sophisticated detection equipment such as a gas chromatograph is necessary. (Thermal conductivity units are not sensitive enough to detect gas levels below 1 g/m^3.)

Sulfuryl fluoride is reputed to have excellent penetrating ability in wood, though specific data are not available. It is very toxic to all stages of insects except the egg stage. Eggs of many insects are tolerant to high concentrations of sulfuryl fluoride. For this reason, APHIS believes that sulfuryl fluoride would do a poor job of killing the egg masses of Asian gypsy moth and nun moth, which may be present on the bark of Soviet logs.

Sulfuryl fluoride is not registered for the fumigation of food, feed, or medicinals destined for human or animal consumption (due to residues), nor on living plants (because of poor tolerance to the treatment). The primary use of sulfuryl fluoride is for control of termites and wood borers. Its efficacy drops sharply at temperatures below 70 °F (21 °C). This fumigant has only limited efficacy against snails. We are not aware of any efficacy studies done with sulfuryl fluoride with respect to nematodes or plant pathogens that may be in wood.

The following sulfuryl fluoride fumigation schedule, taken from Section VI of the PPQ Treatment Manual (APHIS 1985), has been used successfully against bark beetles and borers. Efficacy of the treatment is based upon the reports of Kenaga (1957, 1961).

T 404 (b)(2) (Bark beetles and borers)
Sulfuryl fluoride at normal atmospheric pressure

64 g/m^3 (64 oz/1,000 ft^3) for 16 h
at 21 °C (70 °F) or above
(48 g minimum concentration at 1/2 h)
(45 g minimum concentration at 2 h)
(40 g minimum concentration at 4 h)
(32 g minimum concentration at 16 h)

64 g/m^3 (64 oz/1,000 ft^3) for 24 h
at 15.5–20.5 °C (60–69 °F)
(48 g minimum concentration at 1/2 h)
(45 g minimum concentration at 2 h)
(40 g minimum concentration at 4 h)
(36 g minimum concentration at 12 h)
(32 g minimum concentration at 24 h)

80 g/m^3 (80 oz/1,000 ft^3) for 24 h
at 10–15 °C (50–59 °F)
(60 g minimum concentration at 1/2 h)
(56 g minimum concentration at 2 h)
(52 g minimum concentration at 4 h)
(48 g minimum concentration at 12 h)
(40 g minimum concentration at 24 h)

104 g/m^3 (104 oz/1,000 ft^3) for 24 h
at 4.5–9.5 °C (40–49 °F)
(76 g minimum concentration at 1/2 h)
(71 g minimum concentration at 2 h)
(66 g minimum concentration at 4 h)
(60 g minimum concentration at 12 h)
(52 g minimum concentration at 24 h)

or

80 g/m^3 (80 oz/1,000 ft^3) for 32 h
at 4.5–9.5 °C (40–49 °F)
(60 g minimum concentration at 1/2 h)
(57 g minimum concentration at 2 h)
(53 g minimum concentration at 4 h)
(49 g minimum concentration at 12 h)
(44 g minimum concentration at 24 h)
(40 g minimum concentration at 32 h)

Do not use a filter containing soda asbestos (Ascarite®) with this fumigant.

In addition to the above, the following sulfuryl fluoride fumigation schedule has been successfully used against termites (APHIS 1985) based upon the research of Stewart (1957) and Minnick et al. (1972).

T 404(c)(2) (Termites)
Sulfuryl fluoride at normal atmospheric pressure

16 g/m^3 (16 oz/1,000 ft^3) for 16 h
at 21 °C (70 °F) or above
(12 g minimum concentration at 1/2 h)
(8 g minimum concentration at 16 h)

24 g/m^3 (24 oz/1,000 ft^3) for 24 h
at 15.5–20.5 °C (60–69 °F)
(18 g minimum concentration at 1/2 h)
(8 g minimum concentration at 24 h)

40 g/m^3 (40 oz/1,000 ft^3) for 24 h
at 10–15 °C (50–59 °F)
(32 g minimum concentration at 1/2 h)
(20 g minimum concentration at 24 h)

Do not use filters containing soda asbestos (Ascarite) with this fumigant.

The guidelines for ship fumigation mentioned for methyl bromide are also applicable to sulfuryl fluoride fumigation of ships.

We recommend that the preceding fumigation schedules not be used on Soviet timber until data become available on their efficacy against the specific plant pathogens and nematodes of concern. Also, the relative ineffectiveness of sulfuryl fluoride against the eggs of some species of insects makes this gas an unlikely candidate for endorsement in this application.

References Cited on Sulfuryl Fluoride

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Saltwater Soaking

Saltwater immersion is generally recognized as a sterilant for many nonmarine organisms. The Japanese recognize submersion in saltwater for 30 days as a quarantine treatment for logs. It is common practice in the United States and elsewhere to store logs in freshwater ponds to reduce the risk of insect infestation during storage. This treatment, however may not eliminate all pests and pathogens found in the interior of the logs. Some species of wood-boring beetles have developmental stages that require up to 2 years to complete deep within the wood. Some pests, even on the bark exterior, may find safety in air bubbles trapped beneath the bark. Interestingly, in 1938 a Swedish entomologist reported that the exposed surfaces of pine logs floating in freshwater were attacked by a cerambycid beetle, *Monochamus sutor*, a well-known vector of pinewood nematode (L. D. Dwinell, pers. comm.).

Even if certain logs are sufficiently dense or could be weighted down so as to be completely submerged, we find no scientific studies on the minimum length of time of submersion required. Moreover, logs in contact with the bottom of a pond (unless lined with concrete) could acquire soil, which is prohibited entry into the United States.

We conclude that saltwater soaking cannot be considered an acceptable treatment for quarantine purposes without specific data. The usefulness of saltwater submersion in controlling pests in timber may be a fertile field for research.

Debarking

Debarking (peeling) of logs before importation could be done in the Soviet Union once debarking equipment is in place. Such treatment would be effective in eliminating pests and pathogens on the surface of the logs, as well as those found within and immediately beneath the bark itself. Debarking would facilitate inspection for the presence of boring insects and reduce the potential for establishment of new infestations. Where inspection or experience indicate that boring pests are present, a treatment that penetrates deeply into the wood (e.g., fumigation) may be required. Inspecting bark on large quantities of logs is a difficult, time-consuming process and may not be practical. Bark removal, if attempted, must be thorough.

From a practical viewpoint, APHIS recognizes that complete removal of every scrap of bark is probably impossible. However, a tolerance level could be established if pests will not escape and subsequent measures do eliminate them.

Removing the bark from logs destined for this country would definitely reduce pest risks and should be encouraged. Many countries that permit log importation require debarking. Performing this action at origin to control Asian gypsy moth would not be effective if the debarked logs were later left in an infested area. Such logs would have to be safeguarded under tarpaulin or in some protected area until loaded on a ship.

Wood Preservatives, Insecticides, and Fungicides

Some of the chemicals used for treating wood include oily liquids (such as creosote oil, carbolineum, shale oil, and coal tar), boron compounds, compounds containing metals (arsenic, lead, mercury, copper, chromium, and zinc), various chlorinated phenolic compounds such as pentachlorophenol, and paints and stains (Van Groenou et al. 1951, Hunt and Garratt 1953). Arsenic, lead, and mercury compounds, although commonly used in the Soviet Union as wood preservatives (Gorshin 1976), are not approved for use or entry into the United States by EPA. These materials are considered dangerous because they emit toxic fumes when heated or when in contact with acid or acid fumes.

Leading modern decay-control agents (Helsing et al. 1984) include dazomet (Mylone®, Salvo®, Basamid®), methyl isothiocyanate (MIT, Vorlex®), metam-sodium (Vapam®, Sistan®), and chloropicrin. Some of these, notably MIT, metam-sodium, and chloropicrin, form residues in wood that are detectable for up to 17 years.

Methods of application include dipping, pressure treating, and injection into drill holes (either directly or in gelatin capsules). Target organisms are mainly wood-decay fungi. The most common purpose of application is to lengthen the useful life of rough timber used for fence posts, marine pilings, bridge timbers, railroad ties, and utility poles.

The literature indicates the following key points on the potential use of these chemicals in quarantine programs:

(1) None of these chemicals would be very effective without debarking unless injected though drill holes. Bark is virtually impenetrable to liquids of all kinds. Drill holes would lessen the value of the logs unless they are not to be used for finished lumber.

(2) The end-use of the timber being imported exerts a definitive influence on the selection of a fumigant. All of the chemicals mentioned leave either unpleasant odors, stains, or both. Also, carbolineum-treated timber cannot be painted and must be used outdoors exclusively.

(3) There is little scientific documentation relating to the use of wood preservatives against specific insects or forest pathogens of quarantine significance. There is little doubt that applying these chemicals protects wood from insects and fungi for long periods of time, often years. However, some insects or pathogens already present deep in the wood may not be killed by topical applications.

(4) Typical radial penetration depth of wood preservatives—even when applied under pressures up to 250 lb/in^2—is approximately 1/8 to 1/4 inch (as

shown by stains in logs cut in cross section). Longitudinal penetration (at the ends of logs) may be up to 30 inches and requires up to several hours to attain. Pests and pathogens actually in contact with the chemical would be killed. However, wood preservatives may not kill insects or pathogens in the interior of the wood due to the failure of the chemical to penetrate adequately.

Recently, the use of bifluoride compounds has been suggested as a means of treating wood. Two such products on the European market (but not presently registered in this country) contain aqueous mixtures of potassium difluoride and ammonium difluoride that are either injected or used as a dip for 5–10 min. Penetration into the wood is typically up to 1 inch by immersion or 3 inches by injection, according to the manufacturer. Wood treated with bifluorides gives off hydrofluoric acid (Becker and Berghoff 1963), which is so corrosive that it can etch glass. Hydrofluoric acid also causes respiratory irritation in humans when inhaled in amounts as low as 30 p/m (Machle et al. 1934).

Though bifluorides give some protection against attack by termites and fungi (Nijman 1983), their main use is preventive. They are used as a drying agent for wood and thus are used as a prepaint treatment to keep wood in its natural condition, giving it a longer service life. According to Becker (1976), fluoride compounds have low efficacy against Basidiomycetes, soft rot fungi, blue-stain fungi, and molds. Newly hatched cerambycid beetle larvae (*Hylotrupes bajulus*) were killed within 12 weeks when wood contained bifluorides at 0.3 kg/m^3 or monofluorides or silicofluorides at 0.2 kg/m^3, but up to 12 months of exposure was necessary to kill larger larvae.

APHIS believes that the use of wood preservative chemicals would not be viable as a stand-alone quarantine treatment for Siberian timber because existing infections and infestations may remain deep in the wood, retaining their potential for dissemination, particularly after the wood is cut into lumber. For quarantine purposes, we are not concerned with long-term preservation of wood from rot and decay; our goal is the rapid elimination of pests and pathogens that accompany the shipment.

Some chemicals may be useful as temporary protectants for logs when applied at the point of origin. It would be a mistake to call them wood preservatives in the strict sense. The ideal chemical or combination of chemicals would have both insecticidal and fungicidal activity. It need not have penetrative ability into the wood because the intent would be to create only a temporary protective barrier at the log surface. These chemicals, however, must have sufficient residual ability to remain effective for the entire voyage from Siberia to the United States. To ensure thorough coverage (including the ends of the logs), we recommend that logs be totally immersed in a solution of liquid chemical, not simply sprayed.

Some chemicals that may be suitable for this purpose include the following (use according to label directions):

Metam-sodium—Fungicide, herbicide, insecticide, nematicide, wood preservative, and soil fumigant.

Lindane—Insecticide, registered for use against bark beetles, Deodar weevil, rhododendron borer, gall aphids, black vine weevil, and many other insects. Uses also include forestry, Christmas trees, structural treatments, and logs and lumber.

Pentachlorophenol—Bactericide, fungicide, and wood preservative.

Copper sulfate—Fungicide, compatible with most insecticides.

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Visual Inspection

Visual inspection is often an important element of entry procedures because obviously infested or diseased material can be excluded from the shipment and/or be detained for treatment. The presence of bark, however, provides cover for many pests or pathogens that would be missed even on intensive visual inspection.

For example, the fruiting bodies of *Meria* spp., serious fungal pathogens, may be present on dead needles lodged in crevices of the bark. Visual inspection can be more effective if the logs are debarked. This not only eliminates hitchhiking pests and those associated with the bark but makes borer holes more visible to the inspector. Some pests are very difficult to detect by visual inspection, particularly microscopic nematodes such as *Bursaphelenchus* spp. Such nematodes require an extraction procedure. Visual inspection either before export or on arrival is complicated by shipment of large volumes of unwieldy cargo such as logs. It is impractical to provide sufficient staff time to inspect such commodities adequately even if doing so is theoretically possible. Visual inspection of logs may be one component of a systems approach but does not stand alone as a quarantine method.

Entry and Processing at Points in the United States Where Colonization Is Unlikely

The designation of certain ports of entry as "safe" would be difficult for a number of reasons, even though there may be no commercial stands of susceptible host timber in the immediate vicinity of the port (or even within several miles). Species susceptible to the pests found on Soviet logs—*Larix, Picea, Pinus, Abies,* and *Pseudotsuga*—are widespread in the United States as cultivated timber and backyard and roadside plantings. Some of the pests (e.g., Asian gypsy moth) have extremely broad host ranges that include hundreds of conifer and hardwood species. Asian gypsy moth would likely find suitable host material at any port of entry. Thus, protection for susceptible hosts would be difficult. In addition, many of the insect pests or pathogens fly or may be carried on the wind over great distances, exposing them to hosts over a large area and increasing the likelihood of their establishment. Thus, although restricting the entry of Soviet timber to certain designated ports may be considered as one safeguard, it could not prevent the spread of exotic pests associated with this commodity. It could be one component in a systems approach, however. APHIS specialists would have to evaluate port locations, imported species of logs, associated pests and pathogens, and nearby hosts on a case-by-case basis to permit importation at specific locations.

Gamma Irradiation

APHIS' Hoboken Methods Development Center has completed an extensive search of the scientific literature on the agricultural and industrial uses of gamma irradiation that are applicable for quarantine treatment of Siberian logs. The library resources of the USDA National Agricultural Library, Beltsville, MD, and Hoboken's quarantine treatment library were used in conducting the search.

Gamma irradiation is presently used to disinfect or disinfest foods, spices, cosmetics, plastics, pharmaceuticals, and medical devices. In addition, gamma irradiation is commonly used to extend the shelf-life of various foods. It has been suggested for use on cut flowers, and as a quarantine alternative to methyl bromide fumigation to control various insects and spider mites. To date, the only quarantine use of gamma irradiation accepted by APHIS has been on fresh Hawaiian papayas for shipment to the U.S. mainland as a quarantine measure against fruit flies (Federal Register 54 (4): 387-392 (1989)). Gamma irradiation technology has not been commercially adopted for various reasons, including the availability of cheaper alternatives (dry heat, vapor heat, or hot water), and resistance on the part of consumers to irradiated foods.

Scientific studies on the applicability of irradiating wood for control of wood-boring pests are few. In a review paper entitled "Irradiation as a Quarantine Measure," British scientist P. B. Cornwell (1966), cites the following conclusions of the Australian Atomic Energy Commission:

> Radiation could be considered for the treatment of logs and prepared timbers, but it would be virtually impossible to engineer a plant capable of treating effectively the wide variety of sizes and shapes of imported packing cases. Thus, if irradiation were used, it would have to be employed in the exporting country where disinfestation is already often carried out; such packing cases are stamped, "Fumigated for *Sirex* wasp," and are certified and accepted by quarantine authorities.
>
> For logs and prepared timbers speculative estimates for irradiation treatment provide cost figures competitive with those for fumigation, but until a specific proposal is made these costs can only be used to indicate an order of magnitude. For example with Cobalt 60 at 50 cents per Curie and timber of density 0.5 [g/cm^3], treatment with a dose of 25,000 krad would cost 60 cents/ft^3, assuming 10 percent efficiency and continuous operation. This compares with present-day fumigation costs for timber in large batches (greater than 50,000 ft^3) of 1 cent/ft^3. The margin is not sufficiently large to provide an incentive but the economics and the commercial exploitation interest in the application would be somewhat different if there was a mandatory requirement by Quarantine authorities to treat all timber, or a species of timber. [The author cites personal communication with J. G. Clouston, Atomic Energy Research Establishment, Sutherland, New South Wales, Australia. The economic figures cited in 1966 are significantly below today's costs for fumigating timber.]

In their literature search, APHIS specialists found only one paper that focuses on the radiation sensitivity of wood-boring insects, a study in Japanese (Yoshida et al. 1975) entitled "Control of the Harmful Insects in Timbers by Irradiation: Doses Required for Kill, Sterilization, and Inhibition of Emergence in Three Species of Ambrosia Beetles (Xyleborini) in Japan." The Yoshida team found that lethal doses (LD_{99}) on the female adults, determined 12 days after gamma irradiation exposure, were 73 krad for *Xylosandras compactus*, 91 krad for *X. germanus*, and 130 krad for *Xyleborus semiopacus*. Sterilizing doses, however, were much lower, in the range of 2 to 4 krad for all three species. Boring capacity and adult emergence were effectively inhibited when adults and pupae were irradiated with 10 to 30 krad.

Gamma irradiation and methyl bromide appear to be quite similar in terms of their ability to kill fungi and bacteria in soil, and both treatments were superior to steam (Eno and Popenoe 1964). However, comparable studies have not been done on wood.

APHIS could obtain no information regarding the efficacy of gamma irradiation of timbers to control plant pathogens, snails, nematodes, and wood-infesting insects other than the three species of ambrosia beetles (Scolytidae) mentioned above. Also, we found no information regarding the depth of penetration of gamma irradiation into various species of logs or possible deleterious effects of gamma rays on the structural integrity of wood itself. It is well documented that radiation changes the status of certain ions in organic materials. For example, irradiated glass objects become tinted, and irradiated paper and fiberboard become brittle and develop an aged, yellowish appearance. Because irradiation of the latter wood products causes them to suffer important degradations, we suspect that irradiating timber may not be a feasible method of controlling pests before bringing logs into the country.

Given the current dearth of information on the effects and effectiveness of gamma irradiation on imported logs and the high costs of constructing a commercial irradiator (probably $5–6 millon), we foresee a "go slow" approach by industry until more research has been completed. A feasibility study would probably have to be funded by the timber industry for log irradiation treatment to become a viable quarantine option. USDA's Agricultural Research Service also has explored gamma irradiation for controlling insects infesting various foods; however, no known studies have been done on wood. APHIS concludes that gamma irradiation is not a viable pest-mitigation measure for logs.

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Electron Beam Irradiation

Electron beam (e-beam) irradiation is similar to gamma irradiation but is generated from machines rather than from a radioactive isotope.

Agriculture Canada is examining the feasibility of using machine-generated rays to meet European import requirements for exclusion of the New World pinewood nematode *Bursaphelenchus xylophilus* from logs and lumber, and to eliminate wood-stain fungi. In theory, preload treatment of this type could be accomplished on Soviet logs bound for the United States before the timber left the U.S.S.R. Capital costs and the logistics of setting up such a system have not been addressed, and information seems totally lacking on the efficacy of e-beams against pests and pathogens of Soviet timber. Such a system, if it proves efficacious and operationally practical, would have one advantage over fumigation in that it would not be affected by wind, temperature, or relative humidity. Electron-beam irradiation has the potential of being efficacious against a wide range of pests. Because of the lack of specific data today, we consider e-beams to be useful only as a potential longrange option.

Seasonal Entry

Although the spread of insects and plant pathogens is greatly minimized because of dormancy and low temperatures in winter, these pests may be present in timber and could spread later, upon warming. If methyl bromide fumigation is to be used as the treatment for imported logs, they must reach a temperature of at least 40 °F before treatment. If fumigation is required, the entry of frozen timber could not be allowed. Seasonal entry might be regarded as a safeguard but not the total answer. It could be one component in a systems approach.

Zones Free of Designated Pests

The prospect of shipping Soviet logs from areas where certain key pests and diseases of concern are known to be absent would be a reasonable safeguard. Pest-free zones, however, require constant monitoring because their pest status is subject to change. Survey methods would have to be available for each pest and pathogen of concern. Many species are hard to detect or may be seen only at times of the year when foliage is present. Because, in the case of Soviet timber, the list of pest and pathogen species is long, it is doubtful that any one area could be designated "pest-free" with respect to all of them. The pest-free-zone concept might best be applied to the pests and pathogens of greatest concern, as part of a systems approach, but it cannot be the sole mitigation measure.

Heat Treatments

Heat, in various forms, has long been used as a nonchemical treatment alternative for fresh commodities not tolerant to fumigation. In actual practice, the killing efficacy of heat treatments depends on both temperature and humidity.

Heat has been proposed as a treatment for Soviet timber. We shall consider the following methods: (1) exposing the logs to steam heat or dipping them in hot water, (2) drying the logs in a kiln, and (3) exposing the logs to microwave (dielectric) energy.

Steam Heat and Hot Water Treatments

Limited information is available on the use of steam heat to kill insects and disease organisms in wood timbers. Two old reports (MacLean 1930, 1932) give tables showing the amount of time needed to raise the internal temperatures of pine logs and lumber to a specified point, using steam at either 260 or 275 °F (127 or 135 °C), on wood with initial temperatures of either 0 or 60 °F (-18 or 15.5 °C).

MacLean gave no efficacy data on steam heat against specific pests. Later, Baker (1969) stated that complete mortality among test organisms (in seeds) occurred within 30 min when the temperature was held at 145 °F (63 °C). In addition, at least one study on steam heat used against powderpost beetles (Lyctidae) exists (Snyder and St. George 1924).

Heat in conjunction with moisture appears to increase the susceptibility of living organisms to thermal killing by the denaturation of proteins, particularly enzymes. In addition, the levels of hydration and thermal injury appear to be directly linked. Steam heat, therefore, kills pests more effectively or at least faster than dry heat.

Much of the information on steam heat pertains to steam under pressure. One alternative would be to introduce pressurized steam into a chamber or kiln that could accommodate logs and lumber. Another alternative would be to dip (soak) the logs in a vat containing hot water. Internal temperatures of a representative sample of logs would be monitored by thermocouples placed in holes drilled to the approximate center of the logs.

A 12-h hot water treatment at 120 °F (49 °C), or 48 h at 109.5 °F (43 °C) sterilized oak wilt fungus in wood (Jones 1973). Although we lack specific data, we can reasonably assume that these regimes of temperature and exposure time would be sufficient to sterilize logs containing other pathogens, nematodes, or insects, and that the same temperatures achieved by steam heat would be equally effective. None of the heat treatments researched by Jones (1973) had any significant deleterious effects on log quality.

Kiln Drying/Dry Heat

Some success in eradication of insects has been shown by the use of dry heat. The penetrative effects of dry heat proceed at a much slower rate than those of steam; therefore, dry-heat treatments take longer. Snyder (1923) prescribed dry-heat treatment of timber for at least 30 min at 180 °F (82 °C) to successfully eradicate *Lyctus* beetle infestations. Under ordinary circumstances, the mechanical properties of wood are not appreciably impaired by a temperature of 180 °F maintained for periods of up to 1 h. Snyder and St. George (1924) performed a series of tests on infested wood using temperatures of specifically 130 °F (55 °C) and upward, maintained for 1.5 h or longer. They reported that 130 °F was the minimum temperature that proved fatal to *Lyctus* beetles and that for effective insect eradication, it is necessary to raise the internal temperature of the wood at least to that temperature. Parkin (1937) noted that a reduction in the relative humidity necessitates an increase in the period of exposure in order to achieve complete kill.

One way to conduct dry heat treatment is to heat the wood in a kiln or well-insulated chamber. A kiln-drying schedule effective against powderpost beetles (*Lyctus* spp., family Lyctidae) was originally published by the Department of Scientific and Industrial Research, Great Britain (1957). This schedule was repeated in the USDA Dry Kiln Operator's Manual (Rasmussen 1961), and Section 6 T404 of the PPQ Treatment Manual (APHIS 1985). This schedule, (T404(b)(4)), is shown on the next page.

Schedule for Killing *Lyctus* Powderpost Beetles and Their Eggs

Dry bulb temperature	Wet bulb depression	Relative humidity	Equilibrium moisture content	Thickness of lumber	Total time after kiln reaches set conditions
°F	*°F*	*Percent*	*Percent*	*Inches*	*Hours*
140	7	82	13.8	1	3
				2	5
				3	7
130	16	60	9.4	1	10
				2	12
				3	14
125	15	61	9.7	1	46
				2	48
				3	50

Larvae of the pine sawyer beetle, *Monochamus* spp. (Coleoptera: Cerambycidae), in spruce, pine, and fir lumber were eliminated by kiln-drying the lumber at 140 °F or 160 °F (60 or 71 °C) for 1 h (Ostaff and Cech 1978). Heat-treating lumber in a kiln at 160 °F was also sufficient to kill pinewood nematodes, *Bursaphalenchus xylophilus* (Dwinell 1990). Treatment time varied with the dimensions of the lumber (e.g., 1 h for 2 x 4's and 4 h for 6 x 6's). It has also been reported that commercial kiln drying would be effective in killing all stages of insect life in wood (Ostaff and Shields 1978). It is the official position of the NAPPO that any control measures for wood nematodes should be aimed not at the nematodes but at their vectors, which are Cerambycid beetles.

It must be pointed out that the kiln-drying tests were all done on lumber, not logs. We conclude that the practicality of kiln drying logs and its effect upon log quality must be confirmed by the timber industry before a final decision can be made on its application.

Microwave (Dielectric) Energy

Microwaves are ultrahigh-frequency electromagnetic fields, produced in the 500 to several thousands megaHertz range. Biological material exposed to microwaves absorbs some of this energy. Dry wood has low dielectric properties and thus remains relatively cool while insects in the wood are heated to beyond their lethal limits. Wood with a high moisture content absorbs much of the microwave energy as heat.

Burdette (1976) studied the effects of microwaves on Anobiid beetles in wood. He reported that in most cases, total mortality of these insects resulted when the final temperature reached 122 °F (50 °C) at 1,500 watts of power. Similar studies have been reported on other insects in wood (Thomas and White 1959, Hightower et al. 1974), insects in grain (Hamid et al. 1968), and nematodes in soil (Heald and Wayland 1975).

There is some uncertainty whether microwaves have a significant effect on fungi. Baker and Fuller (1968) reported that successful treatment depended upon moisture content of the soil samples they tested. They stated that the electrical power requirements were excessive for practical use.

We conclude that microwave energy as a quarantine treatment for logs and lumber remains uncertain, particularly with regard to efficacy against pathogens. Much additional research would be needed before we could accept this as a quarantine treatment for Soviet timber.

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Approach

Specialists from APHIS' Science and Technology Methods Development Center at Hoboken, NJ, examined the mitigation measures identified, and judged their efficacy for application to the list of pests provided by the FS pest risk assessment team. Literature citations were seldom available for the specific pests involved, but if the preponderance of evidence indicated that a measure would be effective, APHIS declared it suitable. The paucity of data in the literature meant that extrapolation of existing data to related species was necessary in many cases. The assessments were made on pests in the sites used by the FS pest risk assessment team: "on the outer surface," "in/under the bark," and "in the wood." Conclusions were made applicable to each entire category if possible.

No attempt was made to make final judgment on operational questions. They will be addressed with the affected industry components if specific treatment protocols are approved by APHIS.

Mitigation of Pests on the Outer Surface

Insects

Lepidoptera—Lymantriidae: Asian gypsy moth (*Lymantria dispar*), nun moth (*L. monacha*); Lasiocampidae: Siberian silk moth (*Dendrolimus sibericus*), *D. pini, D. punctatus.*

Latta and Gaddis (1941 unpubl.), working with the strain of gypsy moth that occurs in the Northeastern United States, did extensive testing on eggs and achieved a mortality of 99.75 to 100 percent with the following schedule: methyl bromide 2.5 lb/1,000 ft^3 for 2.5 h at 45–62 °F (7.2–16.6 °C). However, Asian gypsy moth has been intercepted as egg masses on Soviet grain ships by Agriculture Canada. Asian gypsy moth females often fly to lights at night and deposit their eggs on ships loading logs. This problem could be resolved by not loading ships at night, by using special lights that do not attract the moth, by using blacklight traps to attract the moths away from the loading dock, by loading in an area free of Asian gypsy moth, or by allowing seasonal entry of Siberian logs (William Wallner, FS, pers. comm.).

Debarking at origin could effectively remove existing egg masses because egg clusters are most often laid in cracks and crevices of bark, not on bark-free wood surfaces. Debarked logs, however, would have to be protected from subsequent Asian gypsy moth egg-laying to completely satisfy quarantine requirements.

Kiln drying would be effective for lumber (Ostaff and Shields 1978), though the process may not be effective for whole logs. Steam heat or hot water are also believed to be effective for all insect pests likely to be on the outer surface of logs.

The phosphine fumigation schedule for "miscellaneous pests," as given on the Phostoxin® label, would also be effective, i.e., 30 to 90 tablets per 1,000 ft^3 of timber for 3 days.

Coleoptera—Root/Stump Insects, Scolytidae (*Hylastes cunicularis* and *Hylurgus ligniperda*); Curculiondae (*Hylobius abietis* and *Hylurgops palliatus*)

Scolytus multistriatus was successfully destroyed with a methyl bromide schedule of 32.9 g/m^3 for 48 h (Hanula and Berisford 1982).

Gamma irradiation of 15 krads was required to destroy all stages of *Cryphalus fulvus* (Yoshida et al. 1974).

Debarking at origin would be effective because these insects are found in and under bark.

Kiln drying would be effective for lumber (Ostaff and Shields 1978), though perhaps not for whole logs. Steam heat or hot water is deemed to be completely effective for all.

Fumigation using methyl bromide, sulfuryl fluoride, or phosphine would also be effective at the dosages given in the PPQ Treatment Manual (APHIS 1985), Section VI, schedules T404(b)(1), T404(b)(2), and T404(b)(3), respectively, as well as the phosphine fumigation schedule for "miscellaneous pests," as given on the Phostoxin label, i.e., 30 to 90 tablets per 1,000 ft^3 for 3 days.

Hemiptera—Aradidae: pine flatbugs (*Aradus cinnamomeus*)

Debarking, kiln drying, steam heat, hot water, or fumigation with methyl bromide, sulfuryl fluoride, or phosphine would be effective. (See details above under "Coleoptera.")

Homoptera—Lachnidae: larch aphids (*Cinara laricis*) and Adelgidae: woolly adelgids (*Adelges laricis* and *A. tardoides*):

Debarking, kiln drying, steam heat, hot water, or fumigation with methyl bromide, sulfuryl fluoride, or phosphine would be effective. (See details above under "Coleoptera.") The PPQ Treatment Manual (APHIS 1985) also gives a methyl bromide fumigation schedule effective against aphids, (T201(g)(1)): 0.75 lb/1,000 ft^3 for 2 h at 70 °F (21 °C) or above. The manual also recommends a hot water treatment of 110–111 °F (43.3–43.8 °C) for 20 min. Because aphids and adelgids are closely related and have similar habits, we believe that any treatment effective against aphids would be effective against adelgids, too.

Homoptera—Scale insects: *Physokermes jezeonsis* (Coccidae), *Aspidiotus cryptomeriae* (Diaspididae), *Lepidosaphes pseudotsugae* (Diaspidadae), *Nuculaspsis tsugae* (Diaspidadae), and *Matsucoccus koraiensis* (Margarodidae)

Debarking, kiln drying, steam heat, hot water, or fumigation with methyl bromide, sulfuryl fluoride, or phosphine would be effective. (See details above under "Coleoptera.")

For soft scales (Coccidae and Margarodidae), methyl bromide fumigation is usually done under vacuum (APHIS 1985, T201(c)(2)), though this would not be practical to do aboard ship. In Australia, however, a coccid scale, *Eriococcus ironsidei,* is successfully fumigated without vacuum with methyl bromide at 55 g/m^3 for 2 h at 80 °F (26.5 °C) or above (Ironside et al. 1978).

For armored scales (including *Lepidosaphes* spp.) the California Commodity Treatment Manual (Fiskaali 1989) prescribes methyl bromide fumigation at 3 lb/1,000 ft^3 for 2 h at 70 °F (21 °C) or above, or 3.5 lb for 2 h at 60–69 °F (15.5–20.5 °C). The PPQ Treatment Manual (APHIS 1985), Section T201(b), gives a similar schedule for use against armored scales on dormant evergreens, covering the temperature range from 40 to 96 °F (4.5–35.5 °C).

For *Aspidiotus perniciosus,* an early research paper found the following methyl bromide treatment effective: 3 oz/1,000 ft^3 for 16 h at 65 °F (17 °C) or above (Mackie 1938).

Pathogens

Melampsora rust (*Melampsora* spp.)
Larch needle cast (*Meria laricis*)
Conifer shoot blight (*Sirococcus strobilinus*)

Kiln drying at 150 °F (65.5 °C) (dry bulb temperature) for 24 h would be effective (Rasmussen 1961). Steam heat or hot water for 12 h at 120 °F (49 °C) or for 48 h at 109.5 °F (43 °C) are completely effective against oak wilt fungus (Jones 1973) and are therefore presumed to be effective against these pathogens as well.

Debarking would also be effective against the listed fungal pathogens, though there is no specific reference on this. Removal of any forest debris accompanying the logs is crucial in avoiding these plant diseases. However, debarking goes a step further in that it removes the chips of bark between which these pathogens may cling.

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Mitigation of Pests In/Under the Bark

Insects

Coleoptera—Scolytidae: engraver beetles (*Ips duplicatus, I.sexdentatus, I. subelongatus, I. typographus,* and *Dendroctonus micans*); Curculionidae: weevils (*Pissodes piniphilus* and *P. harcyniae*)

Scolytus multistriatus was successfully destroyed with a schedule of methyl bromide 32.9 g/m^3, at unspecified temperatures for 48 h (Hanula and Berisford 1982).

Irradiation of 15 krads was required to destroy all stages of *Cryphalus fulvus* (Yoshida et al. 1974).

Kiln drying would be effective (Ostaff and Cech 1978) for lumber. Because these insects occur in the bark, debarking would be effective, though there is no specific reference to establish this as a fact. Fumigation at the schedules recommended in the PPQ Treatment Manual (APHIS 1985)—T404(b)(1) (methyl bromide), T404(b)(2) (sulfuryl fluoride), and T404 (b)(3) (phosphine)—are all considered to be effective. Penetration would not have to be deep to be effective. Steam heat or hot water are considered to be effective for all pests in or under the bark.

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Mitigation of Pests in the Wood

Insects

Coleoptera—Cerambycidae: *Monochamus urussovi, M. sutor, Xylotrechus altaicus.*

Heat treatment at 140 or 158 °F (60 °C or 70 °C) for 1 h kills all stages of *Monochamus urussovi* (Ostaff and Cech 1978). This could be accomplished in a kiln. Steam heat or hot water could also be used.

Hymenoptera—Siricidae: *Paururus* spp., *Urocerus* spp., *Xeris* spp., and *Sirex* spp.

Urocerus gigas and *Sirex juvencus* have been shown to be somewhat tolerant to methyl bromide (Harris 1963); however, many Siricids were controlled at 2 lb/1,000 ft^3 for an unspecified duration (McMullen 1953).

Fisher (1955) recommends a heat steaming treatment at 165 °F (74 °C) for 10 h as the most reliable and practical treatment for *Sirex*.

Fumigation schedules recommended in the PPQ Treatment Manual (APHIS 1985)—T404(b)(1) (methyl bromide), T404(b)(2) (sulfuryl fluoride), and T404(b)(3) (phosphine)—are all considered to be effective against wood-boring insects.

Kiln drying would be effective for lumber (Rasmussen 1961).

Pathogens

Larch canker (*Lachnellula willcommii*)
Annosus root rot (*Heterobasidion annosum*)
Staining or vascular diseases (*Ophiostoma* spp., *Leptographium* spp.)
Red ring rot (*Phellinus pini*)

Kiln drying at 150 °F (66 °C) (dry bulb temperature) for 24 h kills all stain and decay fungi (Rasmussen 1961). Rasmussen's data were taken from experiments on lumber; kiln drying of whole logs may not yield identical results. Steam heat or hot water 120 °F (49 °C) for 12 h or 109.5 °F (43 °C) for 48 h are completely effective against oak wilt fungus (Jones 1973) and are therefore presumed effective against other pathogens as well.

Nematodes

Pinewood nematodes (*Bursaphelenchus kolymensis*, and *B. mucronatus*)

Effective control of *B. xylophilus* has been demonstrated by kiln-drying at 160 °F (71 °C), bringing the wood temperature to 140 °F (60 °C) (Dwinell 1990a). Heat has also been shown to be effective at 122 °F (50 °C) for 24 h and at 118 °F (48 °C) for 72 h (Dwinell 1990b).

Phosphine fumigation at 4 g/m^3 for 5 days gave 98.1-percent control of *B. xylophilus* in wood chips (Davis et al. 1987); complete kill, however, would require a higher dosage, which has not yet been determined. The gas must penetrate to the center of the log to be effective. Methyl bromide fumigation looks promising, but data have not been published (Dwinell, pers. comm.).

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Summary Table—Mitigation measures available for pests and pathogens associated with larch timber from the Soviet Union

	MB	SF	PH	KD	SH	IR	DB
Pests on the outer surface							
Asian gypsy moth (*Lymantria dispar*) Nun moth (*Lymantria monacha*)	E	N	E	E	E	R	E
Root/stump insects (Scolytidae, Curculionidae) *Hylastes, Hylurgus, Hylobius, Hylurgops*	E	E	E	E	E	E	E
Scale insects (*Physokermes, Aspidiotus, Lepidosaphes, Nuculaspis, Matsucoccus*)	E	E	E	E	E	R	E
Flatbugs (*Aradus cinnamomeus*)	E	E	E	E	E	R	E
Aphids (*Cinara sp.*) Wooly adelgids (*Adelges* spp.) Siberian silk moth (*Dendrolimus sibericus*)	E	E	E	E	E	R	E
Pathogens Melampsora rust (*Melampsora sp.*) Larch needle cast (*Meria laricis*) Conifer shoot blight (*Sirococcus strobilinus*)	R	N	N	E	E	R	E
Pests in or under the bark							
Engraver beetles (*Ips duplicatus, I. sexdentatus, I. subelongatus, I. typographus, Dendroctonus micans*)	E	E	E	E	E	R	E
Weevils (*Pissodes* spp.)							
Pests in the wood							
Monochamus urussovi, Xylotrechus altaicus	E	E	E	E	E	N	N
Siricidae (*Paururus, Xeris, Sirex*)	E	E	E	E	E	N	N
Pathogens Larch canker (*Lachnellula willcommii*) Annosus root rot (*Heterobasidion annosum*) Staining/vascular diseases (*Ophiostoma sp.*) Red ring rot (*Phellinus sp.*) *Leptographium spp.*	R	R	R	E	E	N	N
Wood nematodes (*Bursaphelenchus kolymensis, B. mucronatus*)	R	R	E	E	E	N	N

Abbreviations:

MB — Methyl bromide fumigation
SF — Sulfuryl fluoride fumigation
PH — Phosphine fumigation
*KD — Kiln drying
SH — Steam heat or hot water dip
IR — Irradiation
DB — Debarking

E — Effective
N — Not effective
R — Requires research

***Note on kiln drying:** This treatment would be applicable to squared and cut lumber but not whole logs.

Onsite Survey

An onsite survey of pest conditions and the availability of mitigation measures in the likely source and shipping areas in the Soviet Far East and Siberia was conducted in July 1991 by four FS scientists and an APHIS representative.

The group included an entomologist, two plant pathologists, an economist, and a port operations specialist. This team visited specific cutting, upper landing, lower landing, and shipping sites near Lesosibirsk, Sheera, and Krasnoyarsk in Siberia; near Khabarovsk in the Soviet Far East; and at the ports of Nachodka and Vostochny.

The investigations confirmed the presence of numerous insect and disease pests on logs similar to those proposed for export to the United States. The locations for pest complexes designated in the FS pest risk assessment as "on bark," "in and under the bark," and "in the wood" were found to be accurate and useful designations. Insects of the genera noted, *Ips, Dendroctonus, Monochamus, Urocerus, Lymantria,* and others, and the plant disease organisms *Ophiostoma* spp., *Heterobasidion annosum, Phellinus pini,* and others were found in most locations. Accuracy of the pest status enumerated in the assessment was verified by specialists in Soviet Forest Institutes in both Siberia and the Far East.

The team examined cutting and handling procedures from forest to port. At every stage in the path from standing timber to offloadable commodity, infestation was present and could be transported to the next stage and eventually into the importing country. One important factor—the rapidity with which felled logs could be infested with disease vectors—was observed at several locations. Within days of cutting, extensive infestations of bark beetles and other insects were present. Protection from reinfestation will be an important factor in any mitigation scheme involving storage or the need for multiple control measures.

The team observed large kilns for drying lumber at several locations. Soviet quarantine authorities indicated that fumigation could be performed, although it is done infrequently if at all now. A plywood fabrication plant at Vladivostok was reported to have a facility employing steam and hot water to heat logs rapidly. APHIS believes that heat is the most promising mitigation measure for pests in Soviet timber. Large volumes of logs are shipped from several Soviet ports, and log handling facilities are available. Large numbers of Asian gypsy moth larvae were noted at the port of Nachodka. In 1991, Canadian quarantine authorities have taken action against several grain ships from Soviet ports because of Asian gypsy moth infestation. APHIS is developing measures to guard against this pest, and they will be applicable to log shipments.

Soviet forest-enterprise officials indicated that export of logs and lumber was desired. They also indicated that mitigation measures could be applied if specific contracts and economic considerations required them, even if suitable facilities to do this work do not presently exist.

Chapter 4—Conclusions

Summary of Mitigation Measures and Gaps in Current Data

A review of the summary table (p. 25) reveals that there are wide gaps in scientific data on the efficacy of various mitigation measures. Further work is needed if any one mitigation measure is to be considered all encompassing in its effectiveness for managing the Siberian timber importation problem. Combinations of two, three, or more mitigation measures, though theoretically feasible, must be evaluated to determine if they are economically or operationally practical.

Of all the mitigation measures assessed, kiln drying, steam heat, and hot water appear most promising. But it is important to remember that data available on kiln drying are for treating squared timbers, not entire logs. Additional research is needed to prove that logs could be heated and dried in a kiln without significant loss of wood quality. Sawn lumber, dried in kilns until it reached 140 °C (60 °C), could be allowed entry.

Methyl bromide fumigation appears promising. In this case, however, the knowledge gap is lack of efficacy data with respect to the specific pathogens of concern. There is abundant data showing that methyl bromide, at high dosages and for relatively long durations, provides quarantine control of the oak wilt fungus, which may occur several inches deep in the wood. More-susceptible pathogens would require a less severe fumigation schedule.

Phosphine fumigation—Needs more research.

Sulfuryl fluoride fumigation—Effective against some insect pests but not others; needs more research.

Saltwater soaking—Possibility, but no scientific studies are available.

Debarking—Would facilitate visual inspection; would eliminate organisms on the surface of the log; would not affect deep wood organisms; would not prevent subsequent oviposition by Asian gypsy moth or some other pests.

Wood preservatives—Some chemicals may be suitable as "sealants" to kill surface pests and contain those deeper within the wood; not practical as a quarantine treatment in itself, but may be combined with fumigation and/or heat.

Visual inspection—One component of a systems approach.

Entry at "safe ports"—Possible as one component of a systems approach.

Gamma irradiation—Not enough data to support a treatment recommendation.

Electron beam irradiation—A long-term option; more research needed.

Seasonal entry—Could be one component of a systems approach.

Zones free of designated pests—Could be one component of a systems approach. May not be practical because of the large number of pests.

Heat treatments—Steam heat or hot water dip would be most suitable; kiln drying or dry heat is suitable as a treatment for lumber, but research using logs is needed; microwave energy a possibility, but more research is needed.

Feasibility of Importation

Importation systems must meet the following conditions to be feasible:

1. Evidence of complete effectiveness against all classes of pests (that is, insects, nematodes, and diseases) is necessary.

2. Protection must be provided against escape of pests from the point of arrival in the United States.

3. Mitigation measures must be commercially feasible.

A system involving a surface protectant and a steam or hot-water bath is the most promising combination available. The system could be applied in two scenarios: (1) a protectant applied in the Soviet Union followed by heat treatment in the United States within a specified period after arrival; or (2) in the Soviet Union, heat treatment followed by a protectant against subsequent reinfestation.

Protectants must be effective against flying insects to the depth of the cambium and must sterilize disease organisms at the surface of the logs. APHIS has concluded that steam or hot-water baths are the most effective method for control of pests. Such a method is used to prepare logs for veneer and plywood manufacture in both the United States and the Soviet Union.

Present data indicate that bringing the logs to a temperature of 120 °F (49 °C) may be satisfactory for diseases but that relatively long exposure periods of (24–48 h) may be necessary. Shorter exposure periods, including a schedule specifying a single final temperature, may require temperatures of 140–158 °F (60–70 °C). In addition to the heat treament, a protectant would be necessary either at the point of origin or after heat treatment, depending on whether the heat treatment takes place in the Soviet Union or the United States.

A systems approach that incorporates fumigation plus kiln drying may also be possible. However, data on fumigation effectiveness for diseases are incomplete, and no adequate system to safeguard milling byproducts (e.g., bark, sawdust, and planer residue) is now available.

If technical efficacy issues can be resolved, APHIS will work with the timber industry to develop operationally feasible import procedures.

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